Interim Development Report 1

for

DESIGN AND DEVELOPMENT OF THREE-WATT K_u-BAND TRAVELING-WAVE TUBE

Covering Period 1 July 1962 to 30 September 1962

MICROWAVE ELECTRONICS CORPORATION
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prepared for

Navy Department, Bureau of Ships, Electronics Divisions
Contract NObsr-87501, Project Serial Number SR0080304, Task 9293
Contract Date: 18 June 1962

ABSTRACT

During the first quarter, an electrical design of the helix structure has been formulated. An electron gun has been designed, and a scaled version constructed and tested. The periodic permanent magnet stack has been designed and the magnet parts have been ordered. Also, preliminary tests of the helix-to-waveguide transition have been conducted, and mechanical design and detailing for the program is nearly complete.

CONTENTS

ILLUSTRATIONS

PART I

1. PURPOSE

1.1 The purpose of this contract is to design and develop a three-watt K_u-band periodic-permanent-magnet-focused traveling-wave tube and to deliver three tubes of a preliminary design. Following this, ten tubes of a final design will be delivered.

1.2 The contract program is made up of five phases, including engineering, design, procurement, production, and reports. These five phases and their subheadings are shown in the Project Performance and Schedule Chart of section III of this report.

1.3 There have been no previous programs at MEC on this contract (Contract NObsr-87501).

2. GENERAL FACTUAL DATA

2.1 Identification of Technicians

Personnel	Hours
Joseph B. Kennedy	168
William E. Waters	5
Robert V. Brick	308
Hillie Alexander, Jr.	4
Douglas P. Costanza	113
Fred M. Sanchez	7
Total	605

2.2 Patents

No patents have been issued during this report period.

2.3 References

2.3.1 C.C. Cutler and M.E. Hines, Proc. IRE, vol. 43, p. 307; 1955.

2.3.2 W.E. Danielson, J.L. Rosenfeld, and J.A. Saloom, Bell Systems Tech J., vol. 53, p. 375; 1956.

2.3.3 G. Herrmann, J. Appl. Phys., vol. 28,p. 474; 1957.

2.3.4 G. Herrmann, J. Appl. Phys., vol. 29, p. 127; 1958.

2.3.5 J.E. Sterrett and H. Heffner, IRE Trans. on Electron Devices, vol. 5, p. 35; 1958.

3. DETAILED FACTUAL DATA

3.1 Initial Design

3.1.1 The basis for the design of the type-M M5046 is an MEC traveling-wave tube which has been in production for some time. Several of the critical dimensions of this tube are listed below.

3.1.1.1	a	= helix mean radius	0.0258 inch
3.1.1.2	δ	= helix wire diameter	0.0095 inch
3.1.1.3	D_r	= alumina support rod diameter	0.040 inch
3.1.1.4	N_o	= helix pitch	52.7 turns/inches

3.1.2 A typical graph of gain versus frequency is shown in Fig. 1. In addition, γa versus frequency is also shown.

3.1.3 A number of advantages are derived from scaling (i.e., displacing the gain curve) to a higher frequency.

3.1.3.1 Falloff of gain evident at the high frequency band edge may be greatly reduced.

3.1.3.2 Band edge efficiency will be enhanced.

3.1.4 The disadvantage of scaling is that beam and helix dimensions will necessarily become smaller. The advantages of scaling, however, greatly outweigh the disadvantages.

3.1.5 A combination of voltage and frequency scaling yield the following critical helix dimensions for the M5046.

3.1.5.1 a = 0.0215 inch

3.1.5.2 δ = 0.008 inch

3.1.5.3 D_r = 0.040 inch

3.1.5.4 N_o = 62.5 TPI

3.1.6 In addition, beam voltage for optimum small-signal gain is

$$V_o = 3025.$$

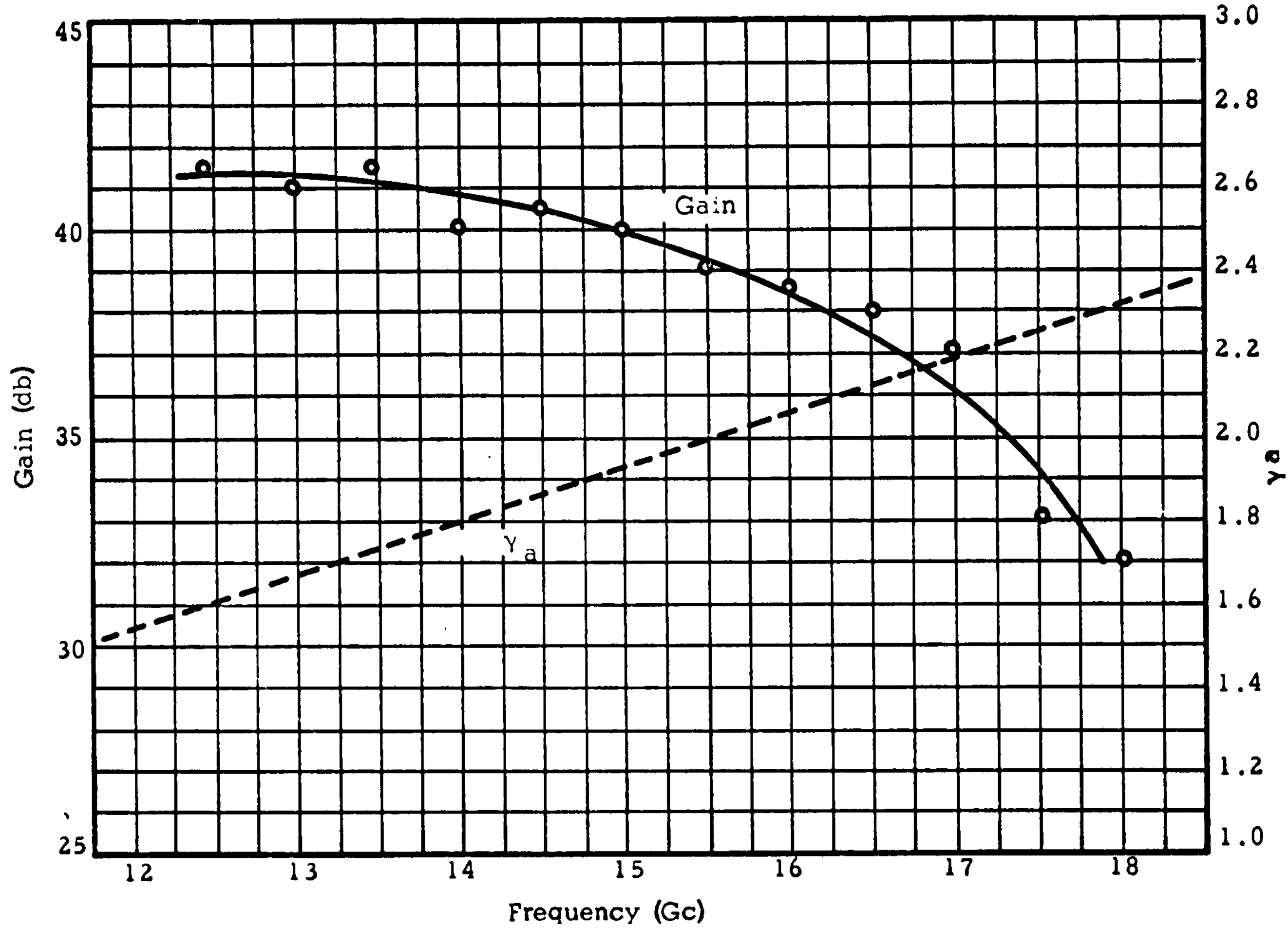

Fig. 1. Gain and γa versus frequency for a TWT which was used as the basis for scaling the M5046. (V_o = 2980 helix volts, I_c = 19.0 collector milliamperes)

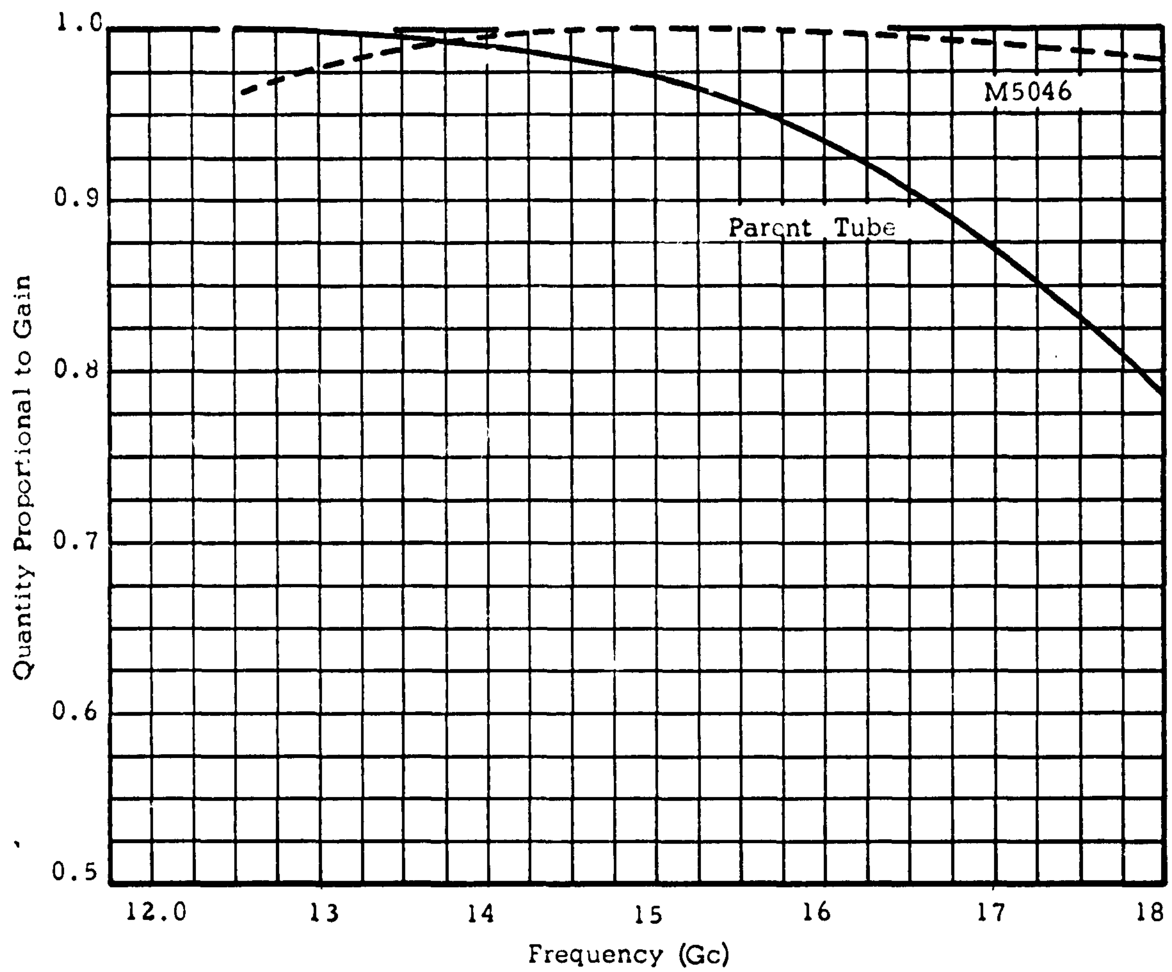

Fig. 2. A quantity proportional to gain versus frequency for the M5046 and the TWT from which it is scaled.

3.1.7 A gain characteristic for the M5046 was determined from Fig. 1 and is presented as Fig. 2. The gain characteristic of the parent tube is included for easy comparison.

3.1.8 A new electron gun has been designed for use with the helix just described. A scaled version of this electron gun has been built and tested in a solenoid at reduced voltage.

3.1.9 Preliminary tests have been made on a waveguide-to-helix transition. This device is similar to transitions presently in use at MEC.

3.1.10 A method of attenuator preparation by pyrolytic deposition of carbon on alumina rods is being pursued. This method of attenuator construction is particularly desirable because it provides a carbon-coated attenuator rod which is extremely stable and which can be readily duplicated.

3.2 Electron Gun and Beam

3.2.1 Minimum efficiency for the M5046 is expected to be greater than five per cent. Therefore, a conservative estimate of the maximum beam power required is 60 watts, and a design perveance for the electron gun was chosen to be

$$K = 0.146 \times 10^{-6} \text{ amps/volts}^{3/2}.$$

3.2.2 Particular care must be exercised in the design of a low-perveance electron gun. Since anode-cathode spacing in inherently large, transverse thermal velocities of electrons emitted at the cathode will cause considerable defocusing of the electron beam, with an attendant loss of laminarity. Further, for a given beam diameter, a large fraction of the total beam current is concentrated on the axis. The result is that beam-circuit coupling is reduced, and large magnetic focusing fields are required. The effect of transverse thermal velocities may be reduced by keeping the cathode-to-beam area compression as small as possible.

However, cathode current density must be maintained at a reasonable value. Cutler and Hines[1*] have described the effect of thermal velocities in electron guns. Danielson, Rosenfeld, and Saloom[2] and Herrmann[3] have provided design information for electron guns of this type. A list of the parameters and dimensions finally selected for the M5046 electron gun are listed below.

3.2.2.1	P = microperveance	0.146 amps x 10^6/volts$^{3/2}$
3.2.2.2	r_{min95} = beam minimum radius	0.011 inch
3.2.2.3	r_c = cathode spherical radius	0.292 inch
3.2.2.4	r_a = anode spherical radius	0.126 inch
3.2.2.5	r_c = cathode button radius	0.045 inch
3.2.2.6	re/σ = ratio of radius of edge of nonthermal electron to radius of standard deviation electron at beam minimum[1,2,3]	3.0

3.2.3 Focusing fields for electron beams of thermally dispersed electron guns typically require higher than Brillouin focusing fields. Herrmann[4] described the effect of thermal velocities on electron beams and includes an expression for computing the focusing field required.

3.2.3.1	B = solenoid field	1058 gauss
3.2.3.2	$\hat{B}$ = peak periodic field	1500 gauss

3.2.3 Sterrett and Heffner[5] have provided a straightforward method for solving the magnetic circuit of a periodic-permanent-magnet-focusing system.

3.2.3.1	L = magnet period	0.413 inch
3.2.3.2	r_1 = pole piece inner radius	0.090 inch
3.2.3.3	R_2 = magnet outer radius	0.238 inch

*See paragraph 2.3 for references.

3.2.4 This magnet stack is designed to provide a peak field of 1820 gauss. The portion of field in excess of the 1500 gauss design value will permit low-temperature compensation. An oriented ferrite magnet material is used.

3.2.5 A scaled-up version of the electron gun was constructed, using a scaling factor of 1.545. This electron gun was placed in an existing tube and focused in a solenoid at reduced voltage. Figure 3 shows the transmission (through a drift tube approximately 5.0 inches long) of this scaled gun. The abscissa is given in the actual solenoid focusing field required. The solenoid field, also scaled by the factor 1.545, is included.

3.2.6 The theoretical solenoid focusing field for 1200 volts is 665 gauss. This is shown in Fig. 3 and is seen to be in a region where the beam is well focused. Further, focusing will improve as beam voltage is increased due to the reduced effect of thermal defocusing. It was necessary to operate the focusing electrode at -6 volts to establish the correct gun perveance.

3.3 Design and Procurement

3.3.1 Design and detailing of the vacum envelope has been completed. Tool design is about 90 per cent complete. Parts, jigs, and fixtures will be ordered early in the next period. Magnets and pole pieces have been ordered.

3.4 Project Performance and Schedule Chart

The Project Performance and Schedule Chart is presented in Fig. 4. It may be seen that all phases of the contract program are on schedule.

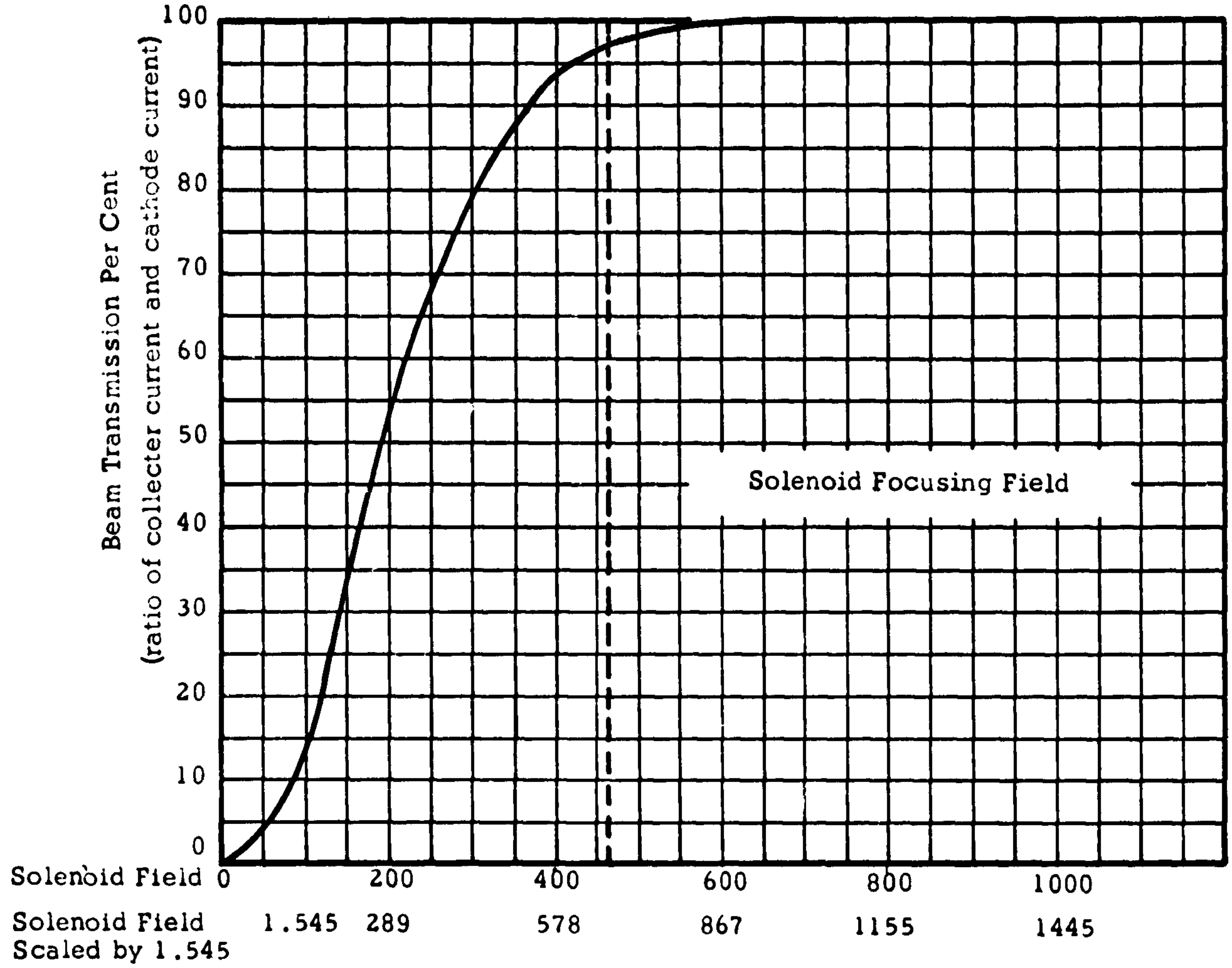

Fig. 3. The M5046 electron beam focusing.

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Project Performance and Schedule
(Project Serial SR0030304, Task 9293)

Contract: NObsr-87501 (Report) Date: 13 November 1962
Contract Date: 18 June 1962 Period Covered: 1 June 1962 - 30 Sept. 1962

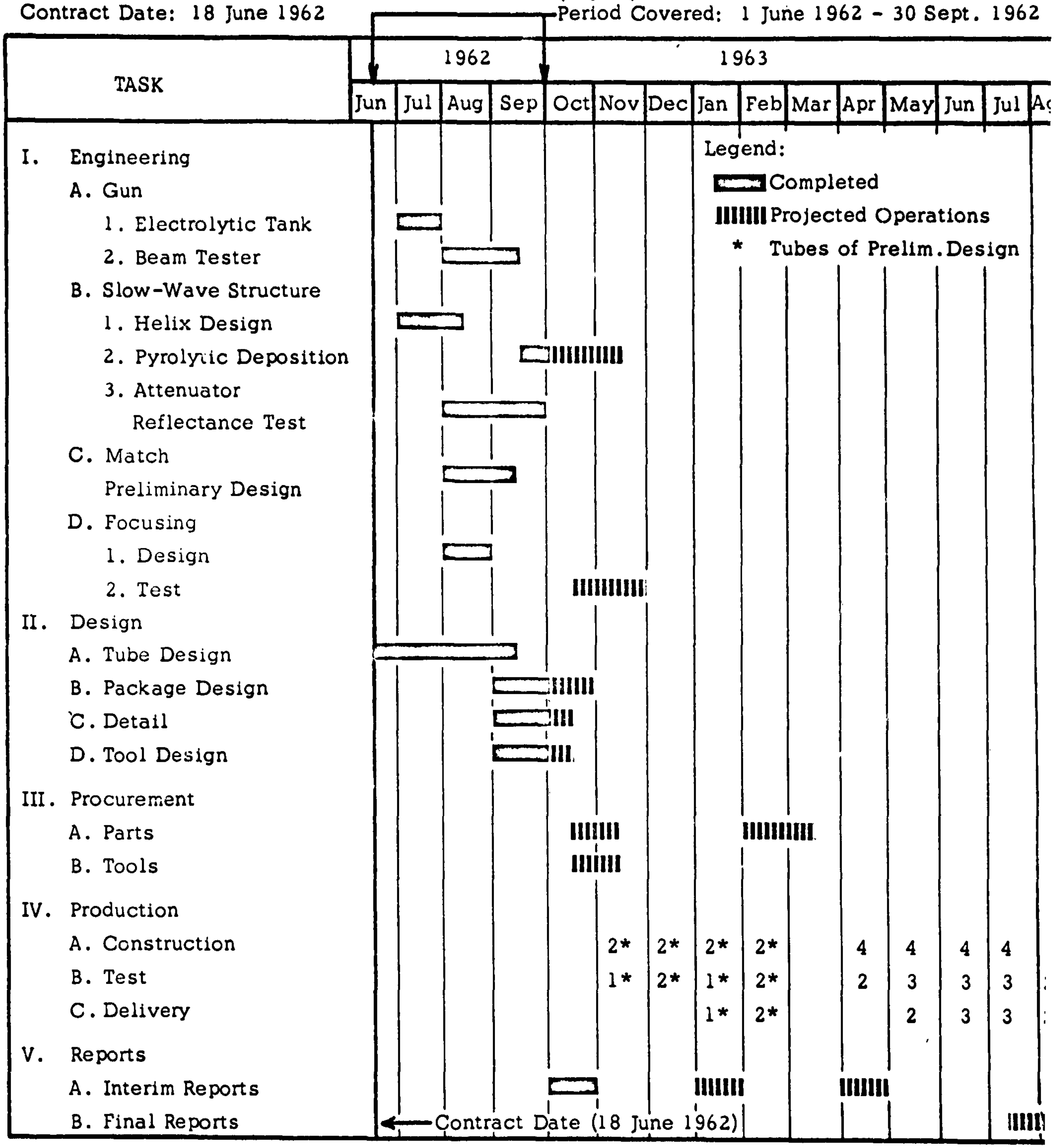

Fig. 4. Project Performance and Schedule

4. CONCLUSIONS

Preliminary design for the K_u-band traveling-wave tube is complete. Work has included evaluation of the scaling of a present TWT, the testing of a scaled electron gun and of a waveguide-to-helix transition, and study of attenuator construction and electron beam action. Design and procurement work is on schedule. No major obstacles have occurred to date. Tube construction should proceed as planned, with the first tube constructed early in the next period.

PART II. PROGRAM FOR NEXT INTERVAL

1. Pyrolylic attenuator rods will be constructed.

2. A periodic-permanent-magnet stack will be assembled and tested.

3. All design and detailing work will be completed. All parts and tools will be ordered.

4. The construction and test of experimental tubes will proceed.